sPHENIX Tracker Review

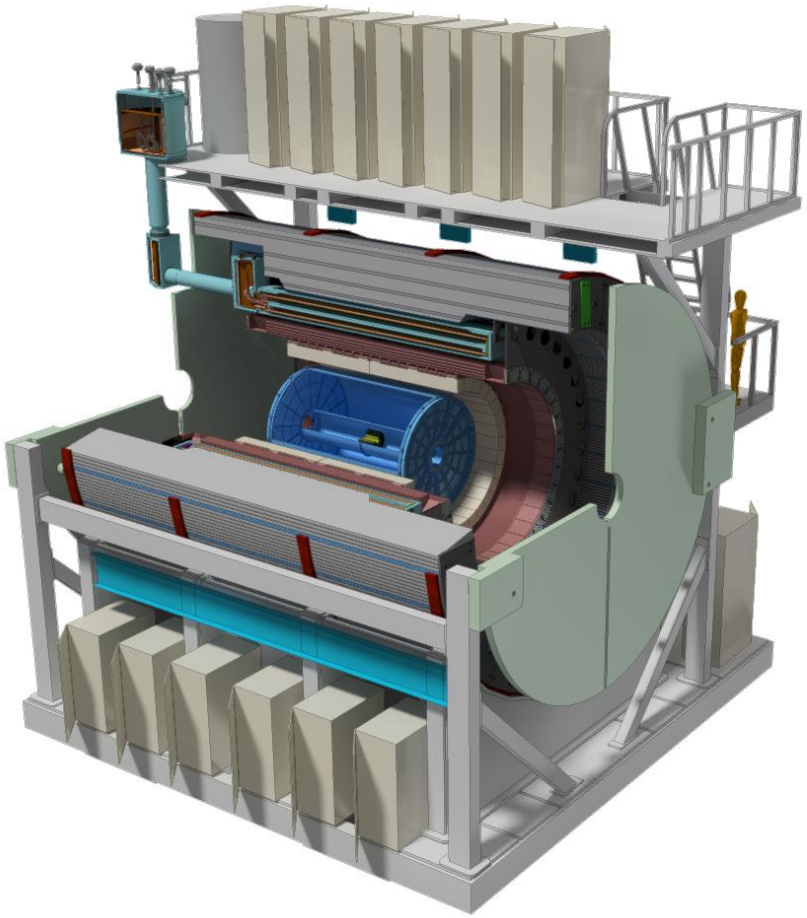
Sept 7-8, 2016

BNL

What is sPHENIX?

- **sPHENIX is a major upgrade to the PHENIX detector. It is a large-acceptance, high-rate detector for Heavy Ion physics that repurposes >$10M in existing PHENIX equipment, infrastructure and support facilities**
- **The detector is optimized to measure jet and heavy quark physics by incorporating a Tracker, full EM and Hadronic calorimeter coverage at $|\eta| < 1.1$, and a 1.5 T solenoidal magnetic field.**
- **It will utilize most of the infrastructure already existing in the PHENIX detector complex and the BaBar SC-magnet**
- **A bottoms-up project plan has sPHENIX assembled, commissioned and ready to take data in January 2022.**

sPHENIX Reference Design



- Uniform acceptance $-1.1<\eta<1.1$ and $0<\varphi<2\pi$
- Superconducting solenoid enabling high resolution tracking
- Hadronic calorimeter doubling as flux return
- Compact electromagnetic calorimeter to allowing fine segmentation at a small radius
- Solid state photodetectors that work in a magnetic field, have low cost, do not require high voltage
- Common readout electronics in the calorimeters
- High rate 15 kHz in AA allows for large unbiased MB data sample
- Utilization of existing 1008 Infrastructure
- Compact TPC + MAPS-vertex +Intermediate Si Strip Tracking(INTT) layers for Tracker

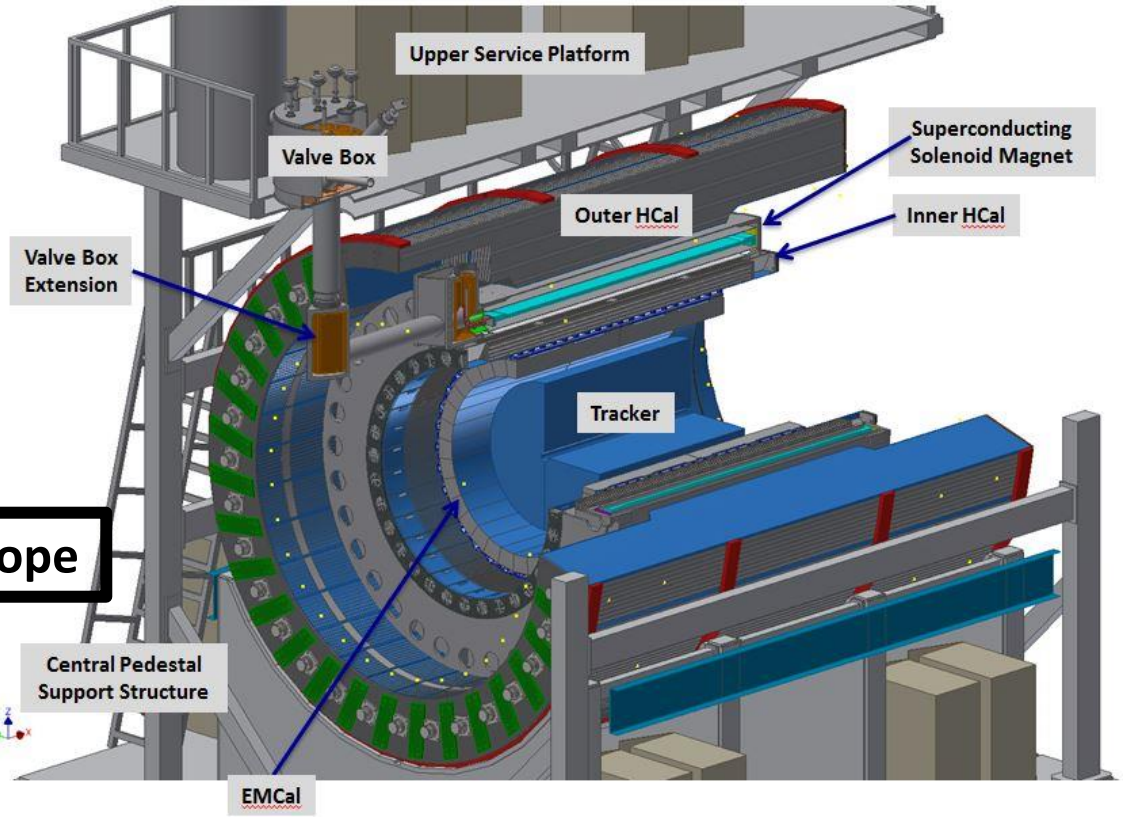
sPHENIX Project Scope and Support Activities

sPHENIX is an MIE project costing 30-35M AY$

1) sPHENIX MIE Project scope:
Project Management
Tracker
EMCal
HCal
Calorimeter Electronics
DAQ/Trigger

2) Ops labor in support of MIE scope

3) Facility upgrade activities in support of sPHENIX:
SC- Magnet (cryo & controls)
Infrastructure
Installation/Integration



Context of the Tracker Review

- The project is pre **CD-0**. We expect **CD-0** in the Fall of 2016.
- All designs are pre-conceptual
- We have chosen technologies for the reference design that allow us to do schedule, resource, costing and contingency planning
- There are a few technical issues that remain open including those in the Tracker subsystem.
  - **Calorimeter systems are in the 2nd round of prototyping**
  - **Tracker systems are in the 1st round, though many key components are copies of existing systems or far-advanced developments**
- A bottoms-up resources-loaded project plan exists for most of sPHENIX though a small number of recent additions to the Project need to complete their plan.
- The earliest we will begin final fabrication is **CD-3b** (4QFY18), two years from now, but we will ask for **CD-3a** at the time of **CD-1** (1QFY18). The **CD-3a** will be for certain long lead time items like SiPMs and HCal steel.
- The RIKEN group has committed to providing a four layer Intermediate Si strip Tracker (**INTT**) with a defined scope to sPHENIX.

Status of sPHENIX

- Positive outcome for the Director's Cost & Schedule review of sPHENIX, Nov 2015
  - **Implemented recommendations to carry 40% contingency at this early stage of project**
  - **Revised schedule to add 8.5 months of project float. New physics start date Jan 2022**
  - **Added Tracker subsystem to Project. Had previously been planned as international contribution.**
  - **Scrubbed the budget numbers**
- Presented sPHENIX funding plan to DOE-ONP Budget Briefing , Feb 2016
- Low power cold test of SC-Magnet in Bldg 912: joint SMD, CAD, Phys effort, Mar 2016
  - **Preparations underway for a full field test in early CY 2017**
- Successful beam test at FNAL of proposed calorimeter technologies in April 2016.
  - **Both EMCal and HCal performance specs met. Next round of tests Jan 2017.**
- sPHENIX scoping and budget exercise, Apr-May 2016
- Received Permission from DOE-ONP to remove existing PHENIX detector after RHIC Run-16 in preparation for a major upgrade. Removal started Jul 2016

Status of the sPHENIX Tracker

The Tracker system has three components:

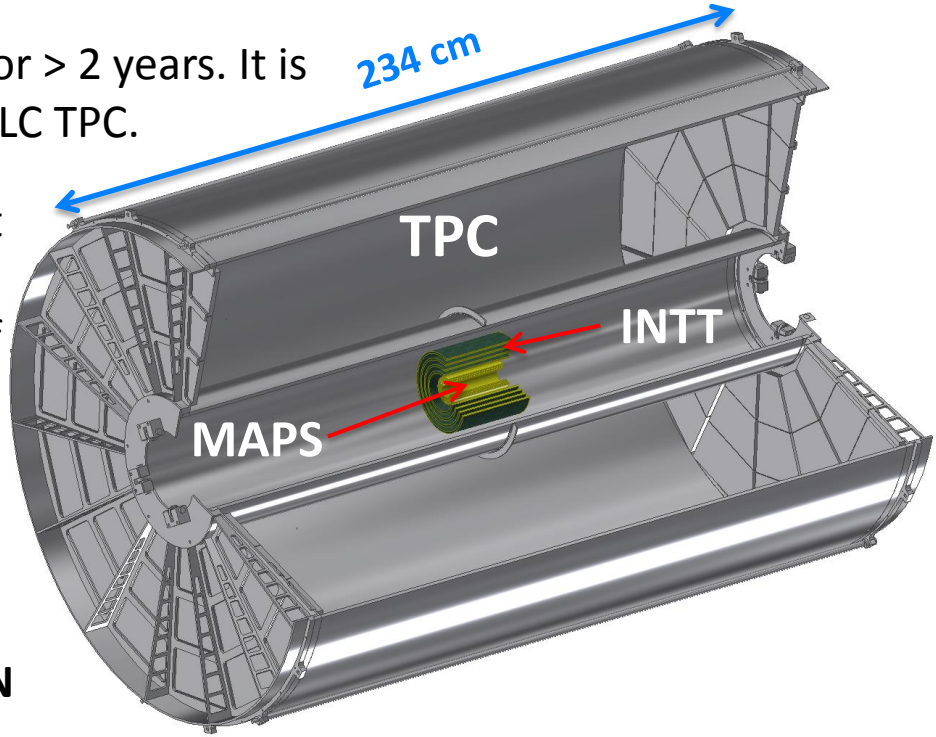
- **Monolithic Active Pixel Sensors (MAPS) Three-layers identical to Inner ALICE ITS (r = 2.3cm, 3.1 cm, 3.9 cm)**
- **Intermediate Silicon Strip Tracker (INTT) Four layer Si strip detector. In kind contribution to sPHENIX from RIKEN. (r = 6 cm, 8 cm, 10 cm, 12 cm)**
- **Compact Time Projection Chamber (TPC) (20 cm < r < 78 cm)**

All cover at minimum $|\eta| < 1.1$ and 2π in azimuth

The **TPC** has been a Tracker option in sPHENIX for > 2 years. It is built on previous work for the STAR, ALICE and ILC TPC.

MAPS was proposed for sPHENIX ~ 1 year ago. It is a direct copy of the Inner 3 layers of the ALICE ITS. It received a recent boost by the approval of a LANL LDRD in support of its development for sPHENIX.

The **INTT** is a new concept in the past few months but is the outgrowth of an earlier all-Si tracker design for sPHENIX .**It is funded by RIKEN**



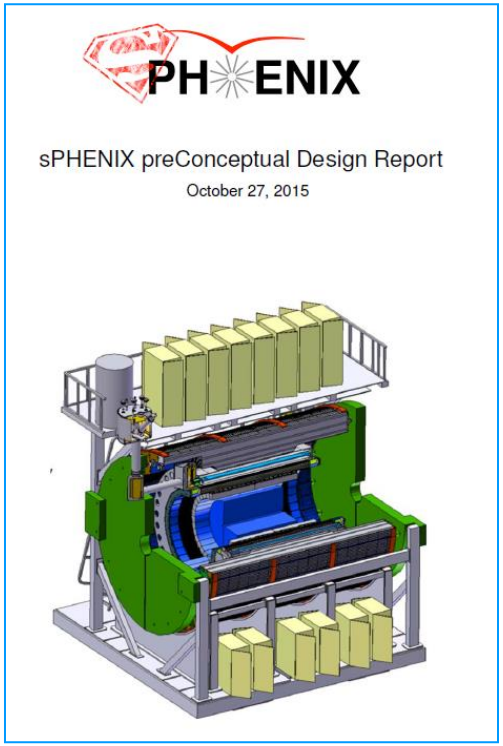
sPHENIX Commitment Letter from RIKEN

Dear Ed,
RIKEN and RBRC Experiment group is working to develop a silicon detector for sPHENIX. In the present plan, the detector is made of 4 layers of silicon strip detector barrels, placed at R=6, 8, 10, and 12 cm from the beam pipe and covering +/-12 cm along the beam. This project is led by Dr. Itaru Nakagawa of RIKEN and supported by Dr. Yasuyuki Akiba, the group leader of RBRC experiment group. Our intention is to provide this detector as an in-kind contribution to sPHENIX, as a part of continuing collaboration of RIKEN and BNL on the RHIC spin physics program. We heard that there is possibility that part of the sPHENIX detector can be de-scoped due to limited budget. We hope our in-kind contribution can help to avoid or to reduce the chance of de-scoping.
Best regards,
Hideto En'yo,
Director, RIKEN Nishina Center

Continuation of a 20 year collaboration between BNL and RIKEN during which time RIKEN has provided a Muon Spectrometer Arm, Si VTX barrel and Muon Trigger to PHENIX and a variety of spin related devices including Siberian snakes and spin rotators to RHIC

Documentation Made Available to the Committee

- Preliminary Conceptual Design Report (Nov 2015)
- WBS and WBS Dictionary for Tracker components
- sPHENIX Science Proposal to DOE plus DOE Review report
- Basis of Estimate Documents for Tracker components
- Preliminary Risk Analysis and Mitigation Document
- Preliminary Safety and Hazard Analysis
- Preliminary Quality Assurance Plan
- Report from Nov 2015 Cost & Schedule review
- TPC and MAPS Project file



We have drafts of almost all docs though some, especially the WBS dictionaries and BOE docs need more detail

sPHENIX Calendar – Many Reviews

• sPHENIX Proposal submitted to DOE	Fall 2012
• **DOE Science Review 1**	**July 2014**
• Revised Proposal	Nov 2014
• **Internal Rev of SC-magnet**	**Dec 2014**
• **Internal Rev of Decommissioning and Installation**	**Jan 2015**
• **Internal Rev of HCal**	**Feb 2015**
• BaBar magnet arrives at BNL	Feb 2015
• **Internal Rev of Calorimeter Electronics**	**Mar 2015**
• **DOE Science Review 2**	**April 2015**
• Org Meeting to form new sPHENIX collaboration	Jun 2015
• **Internal Rev of EMCal**	**Aug 2015**
• **BNL-charged Cost and Schedule Review**	**Nov 2015**
• Formation of new collaboration	Dec 2015
• Election of Spokespersons/Executive Council	Jan-Apr 2016
• **Internal Rev of TPC/Tracker**	**Jun 2016**
• **Internal Review of MAPs-vertex/Tracker**	**Jul 2016**
• **BNL-Charged Tracker review**	**Sept 2016**

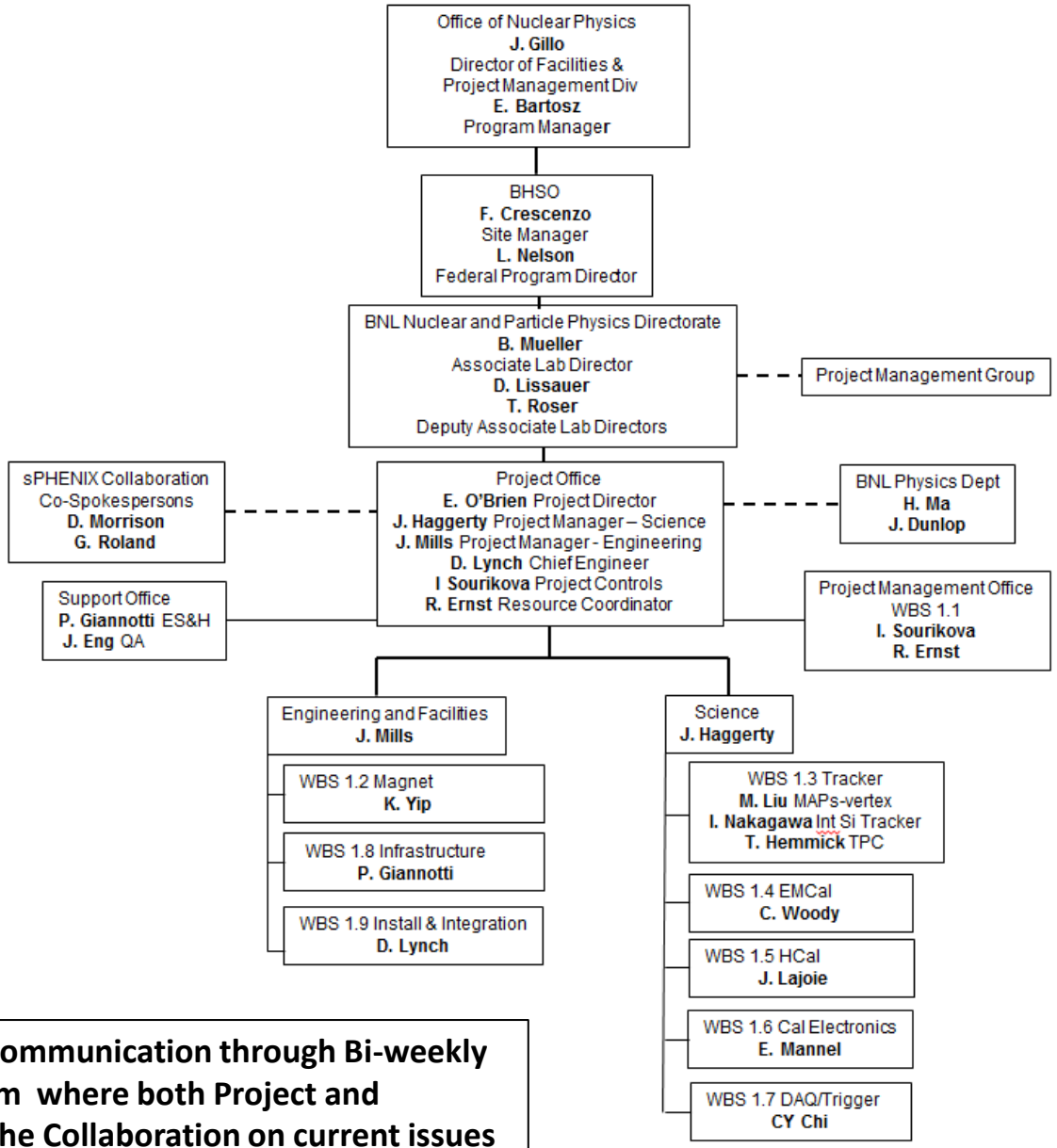
In addition there have been numerous simulations workshops & topical reviews and approximately 500 sPHENIX meetings archived on Indico

Projected Future sPHENIX Schedule

CD-0	Fall 2016
Director's Cost and Schedule Review	Nov-Dec 2016
Test Beam at FNAL(2nd round prototyping)	Jan 2017
OPA-CD-1/CD-3a Review	May-Jun 2017
CD-1/CD-3a authorization	Nov-Dec 2017
All Preproduction R&D and Design complete	May-Jun 2018
OPA- CD-2/CD-3b review	May-Jun 2018
CD-2/CD-3b authorization	Jul-Aug 2018
sPHENIX Installed, cabled, ready to commission	Apr 2021
First RHIC beam for sPHENIX	Jan 2022

The Resource-loaded Schedule contains 8.5 months of float to Jan 2022

Project Organization

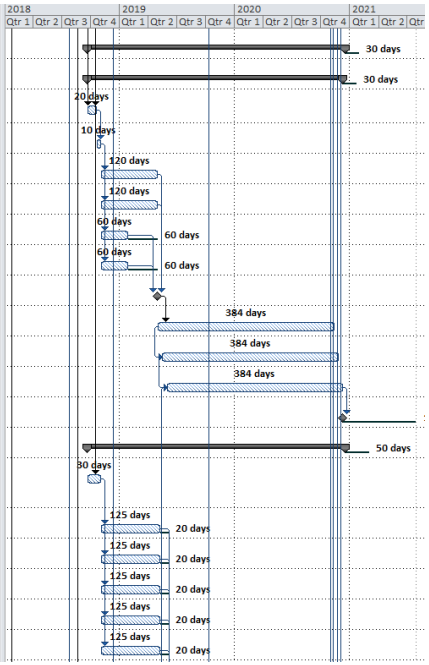


Project-Collaboration communication through Bi-weekly General Meeting. Forum where both Project and Spokespeople update the Collaboration on current issues

Status of Project Planning

- sPHENIX resource-loaded project plan has been created to account for DOE schedule guidance, latest subsystem updates, new labor resource sheets with FY16 rates, and explicit separation between MIE tasks (DOE 413.3b reportable) and off-project support tasks. Plan has existed since the fall of 2015 and has been regularly updated to account for design evolution.
- Input from Project Management team, L2 & L3 managers, subsystem engineers. Approximately 40 people contributed to the Project Plan.
- >1600 tasks total. The project file is fully resource -loaded and linked (22 files total in MS-Project)

WBS	Name	Duration	Start	Finish	Resource Names	Fixed Cost
1.4.4	**EMCal Production**	**559 days**	**Wed 6/20/18**	**Wed 9/16/20**		**$0**
1.4.4.1	**EMCal Tower/Module Production**	**554 days**	**Wed 6/20/18**	**Wed 9/9/20**		**$0**
1.4.4.1.1	Update Design for Fabrication and Assembly	20 days	Wed 6/20/18	Thu 7/19/18	SCI3 PO[10%],PROF4 PO M[20%],TECH3 PO D[20%]	$0
1.4.4.1.2	Production Readiness and Safety Review	10 days	Fri 7/20/18	Thu 8/2/18	STUDENT[10%],SCI3 PO[50%],PROF3 PO M[50%],TEC	$0
1.4.4.1.3	Procurement of calorimeter materials	120 days	Fri 8/3/18	Tue 1/29/19	SCI3 PO[20%],PROF4 PO M[20%]	$0
1.4.4.1.4	Establish Fabrication contract	120 days	Fri 8/3/18	Tue 1/29/19	PROF3 PO M[10%]	$0
1.4.4.1.5	Fabricate tooling for mass production	60 days	Fri 8/3/18	Fri 10/26/18	TECH3 PO M[200%]	$50,000
1.4.4.1.6	Set up factory for mass production	60 days	Fri 8/3/18	Fri 10/26/18	TECH3 PO M[200%]	$20,000
1.4.4.1.7	Start Module Fabrication	0 days	Tue 1/29/19	Tue 1/29/19		$0
1.4.4.1.8	Fabricate modules	384 days	Wed 1/30/19	Tue 8/11/20	STUDENT[600%],SCI3 PO[50%],TECH3 PO M[700%],T	$3,680,000
1.4.4.1.9	Test modules in factory	384 days	Wed 2/13/19	Tue 8/25/20	STUDENT[200%],SCI3 PO[50%],TECH3 PO M	$10,000
1.4.4.1.10	Test modules as delivered	384 days	Thu 2/28/19	Wed 9/9/20	STUDENT[200%],SCI3 PO[50%],TECH3 PO M[50%]	$10,000
1.4.4.1.11	EMCal Module Production Complete	0 days	Wed 9/9/20	Wed 9/9/20		$0
1.4.4.2	**EMCal Module/Sector Assembly**	**559 days**	**Wed 6/20/18**	**Wed 9/16/20**		**$0**
1.4.4.2.1	Update any design changes based on FS prototype, Factory Input and Final Design Review	30 days	Wed 6/20/18	Thu 8/2/18	SCI3 PO[20%],PROF4 PO M[50%],TECH3 PO D[50%]	$0
1.4.4.2.2	Fabricate mechanical parts	125 days	Fri 8/3/18	Tue 2/5/19	TECH3 PO M[300%],TECH3 PO E	$250,000
1.4.4.2.3	Fabricate parts for light collection system	125 days	Fri 8/3/18	Tue 2/5/19	TECH3 PO M[200%]	$75,000
1.4.4.2.4	Fabricate parts for readout system	125 days	Fri 8/3/18	Tue 2/5/19	TECH3 PO M[200%]	$50,000
1.4.4.2.5	Fabricate parts for calibration system	125 days	Fri 8/3/18	Tue 2/5/19	TECH3 PO M[200%]	$50,000
1.4.4.2.6	Fabricate parts for auxillary systems	125 days	Fri 8/3/18	Tue 2/5/19	TECH3 PO M	$50,000



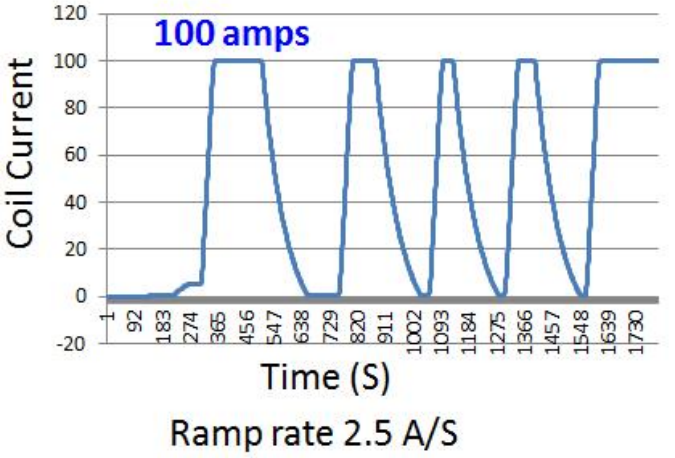
Support for Progress on sPHENIX Hardware

Both BNL and outside support have been invaluable in support of generic R&D and feasibility studies:

- BNL has provided funds for the relocation and testing of the BaBar SC-magnet
- BNL has also provided LDRD and Program Development funds to support generic R&D on Calorimetry and Tracker(TPC) technologies of potential use for sPHENIX.
- The EMCal and TPC design have both benefitted for technology developments made possible by EIC generic R&D
- The MAPS-vertex has received significant LDRD support from LANL
- Japanese funds are being used to support R&D of the Intermediate Tracker which would be a 4 layer Si strip detector.

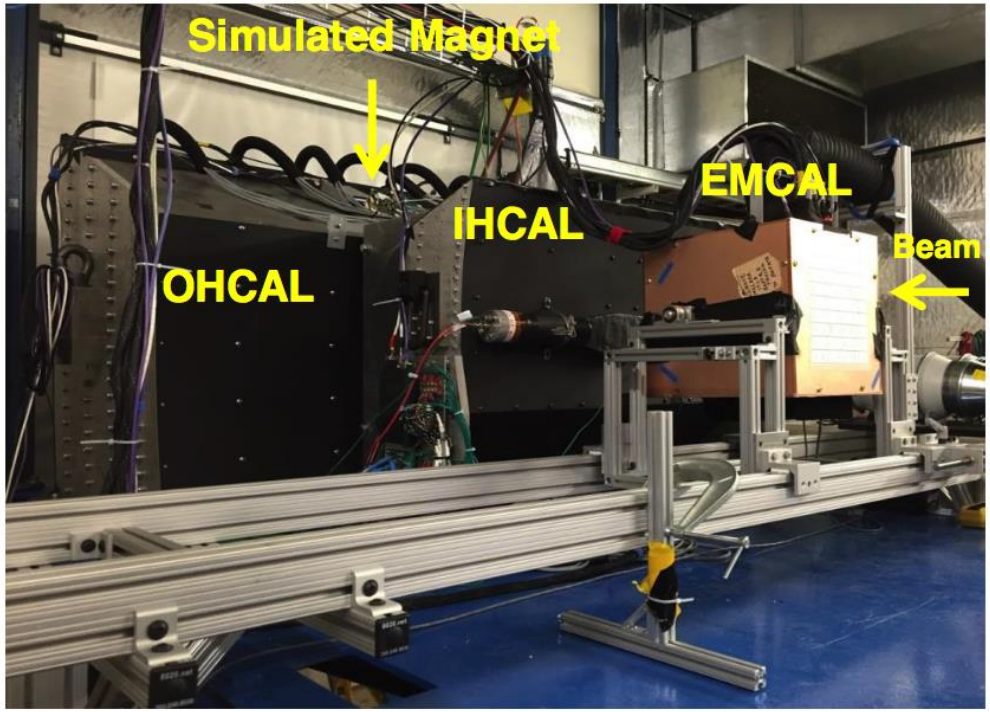
Low-Field Test of sPHENIX Magnet - Mar 2016

The sPHENIX Magnet was successfully cooled to 4K and ramped to 100A. The field measure was exactly as expected for this current. Test was a combined effort of techs, engineers and scientists from SMD, CAD and Physics Dept.



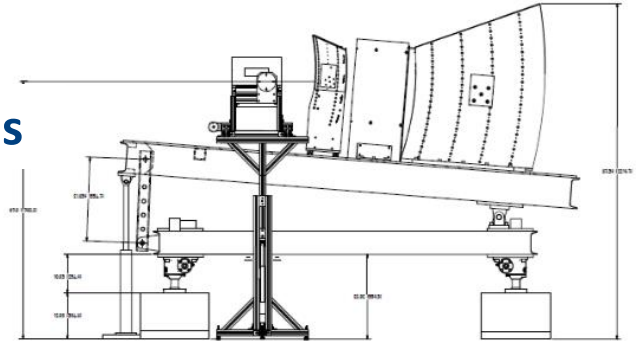
Prototyping Various Calorimeter Technologies Using a Test Beam Set Up at FNAL

All three prototype calorimeters in the beam line at Fermilab



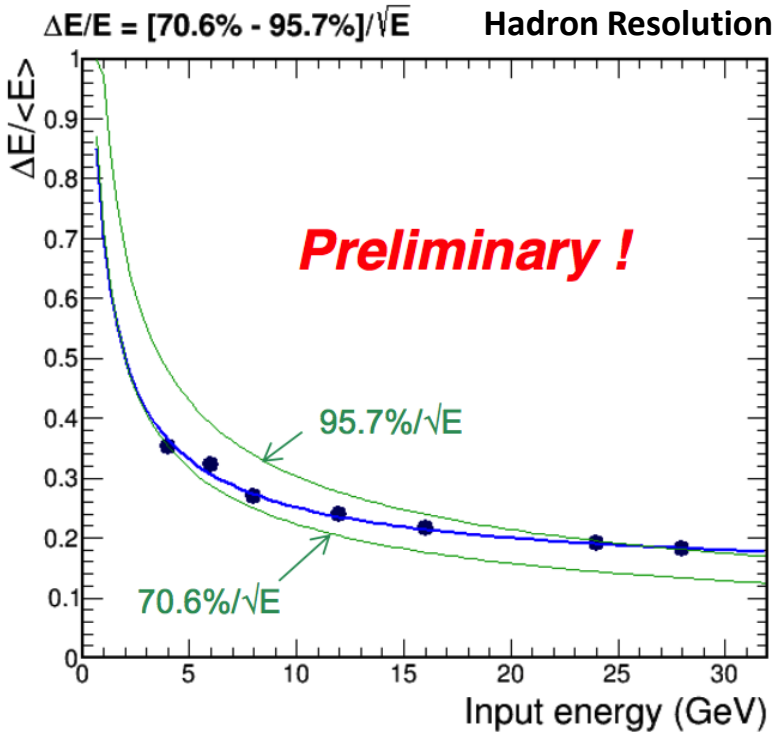
Work supported by BNL Program Dev & LDRD funds

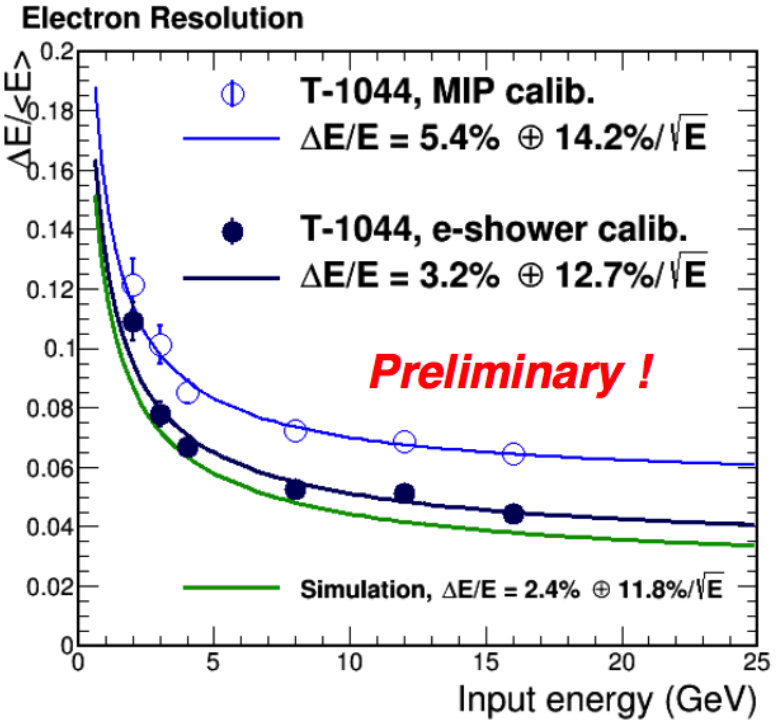
Measured at three tilt angle positions (0, ± 4.5°)



Calorimeter Test Results

Calorimeter Performance Specs Met





- Combined energy resolution meets our design goal of < 100%/√E
- Two component fit gives 68%/ √E + 12.9%

- EM resolution meets our design goal of 15% /√E
- Two component fit using EM shower calibration gives 12.7%/ √E + 3.2%

sPHENIX Budget Profile: MIE

Budget Estimate as of April 2016

M&S for the Detector Project including Project Management, Tracker, EMCal, HCal, Calorimeter Electronics, DAQ/Trigger. Project Management Labor split between the MIE and Ops Support.

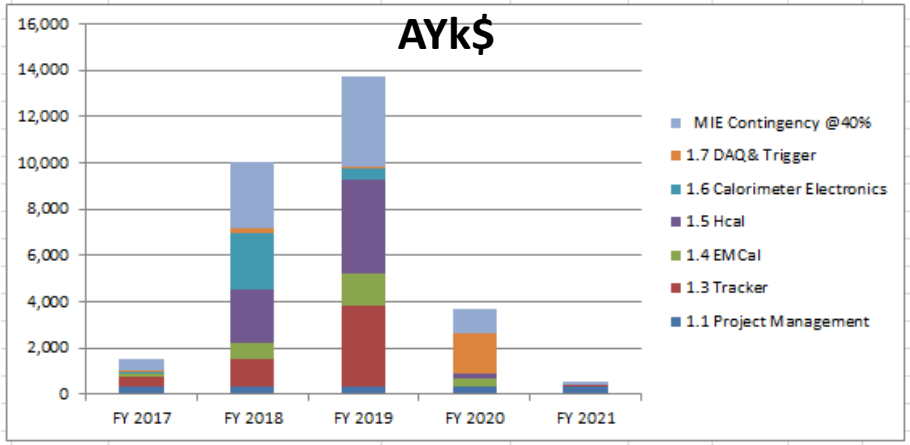
MIE Total = 29,500 AYk$

Since that time:

- TPC has created a bottoms-up cost estimate including a resource-loaded schedule
- MAPS has been added to sPHENIX. It has created a cost estimate based on the ALICE ITS
- INTT has been added to the project as a RIKEN contribution.

The TPC is part of the sPHENIX MIE. MAPS may be part of the MIE but might also be funded as an independent project through a consortium of sPHENIX collaborating institutions. INTT is not part of the MIE but its schedule, milestones, etc. will be followed as if part of the project.

Category A: sPHENIX MIE



Descope Scenario

AY k$'s - with Extraordinary Construction Overhead Application

WBS	SYSTEM	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	Total
1.1	Project Management	370	370	370	370	370	1,850
1.3	Tracker	374	1,186	3,447	0	13	5,020
1.4	EMCal	127	647	1,401	353	0	2,527
1.5	Hcal	0	2,353	4,044	166	0	6,562
1.6	Calorimeter Electronics	120	2,444	515	0	0	3,079
1.7	DAQ& Trigger	80	190	29	1,726	0	2,025
	Baseline Total	1,070	7,189	9,806	2,615	383	21,063
	MIE Contingency @40%	428	2,876	3,922	1,046	153	8,425
	MIE Total	**1499**	**10064**	**13728**	**3661**	**536**	**29488**

WBS	SYSTEM	Baseline	Contingency	Total
1.1	Project Management	1,850	740	2,590
1.3	Tracker	5,020	2008	7,027
1.4	EMCal	2,527	1011	3,538
1.5	Hcal	6,562	2625	9,187
1.6	Calorimeter Electronics	3,079	1232	4,311
1.7	DAQ& Trigger	2,025	810	2,835
	MIE Totals	**21,063**	**8,425**	**29,488**

Includes project scope reductions

Issues and Concerns

- The Tracker design has rapidly evolved over the last year. Need to keep up the momentum and continue to expand the institutions working on both the Tracker and other sPHENIX subsystems.
  - **This is especially true on MAPS were we would like to transform institutional interest into commitments over the next few months.**
- sPHENIX needs to be ready for the RHIC 2022 run starting Jan 2022. This will require significant cooperation and coordination between BNL, sPHENIX and DOE to guarantee resource availability when required.
- Remaining open technical and design issues should be resolved soon so that the project can proceed smoothly to CD-1/CD-3a followed soon after by CD-2/CD-3b.
  - **The fast pace of retirement of technical risk must continue through prototype construction, bench and beam tests**
- Need to expand the participation of sPHENIX institutions on project tasks. The eventual success of the project will be determined by the level of participation of collaborators from outside of BNL.

Summary

- sPHENIX has acquired the former BaBar SC-magnet and has performed successful warm and low-power cold test. A full-field cold test is scheduled for early CY2017.
- Good progress has been made in qualifying detector technologies and retiring technical risk with work supported by LDRD, Program Development, generic R&D and non-DOE funding.
- The Project Management team has been working together for > two years. The sPHENIX collaboration formed in Dec 2015 with election of Co-spokespeople Jan 2016.
  - **The project & collaboration have a very busy slate of meetings, reviews, workfests …**
  - **Recent commitment of RIKEN to provide subdetector to sPHENIX is a very important development**
- Resource-loaded bottoms-up cost estimate exists. Revised to incorporate recommendations of Cost and Schedule review, and additional BNL and DOE guidance.
  - **Updated cost information from vendors will be updated by mid-Fall 2016**
  - **The Project plan, budgets and schedules are updated often, at least once/quarter**
- There are a few open technical decisions yet to be made, but they are significantly less than 1 year ago. Some remaining are:
  - **Detailed implementation of TPC readout chain**
  - **Define MB Trigger device**
  - **Develop mass production techniques for EMCal towers**

Back-Up

TPC : Fully Burdened Bottoms-Up Cost Estimate

sPHENIX TPC Tracking

Summary Estimate

	2016	2017	2018	2019	2020	2021	2022	Grand Total
sPHENIX Labor								
Fixed FY16 Direct Labor w/fringe		**372,981**	**493,559**	**551,504**	**149,820**			**$1,567,864**
Estimated Composite Indirect on Labor@36.9%	0	137,630	182,123	203,505	55,284	0	0	578,542
Fixed FY16 Fully Loaded Labor	**0**	**510,611**	**675,682**	**755,009**	**205,104**	**0**	**0**	2,146,406
Escalation @ 3.0%	0	15,318	41,149	69,989	25,740	0	0	152,197
Subtotal AY $	**0**	**525,929**	**716,831**	**824,998**	**230,844**	**0**	**0**	2,298,603
Contingency at 40%	0	210,372	286,733	329,999	92,338	0	0	919,441
Budgeted Labor	**0**	**736,301**	**1,003,564**	**1,154,998**	**323,182**	**0**	**0**	**3,218,044**
Adjusted sPHENIX M&S - TPC		**$324,866**	**$736,169**	**$893,000**	**$5,000**			**$1,959,035**
Estimated Composite Indirect	0	30,635	69,421	84,210	472	0	0	184,737
Subtotal FY 16 $	**$0**	**$355,501**	**$805,590**	**$977,210**	**$5,472**	**$0**		**$2,143,772**
Escalation @ 2% per FY	0	7,110	32,546	59,813	451	0		99,920
Estimate with Escalation	**$0**	**$362,611**	**$838,136**	**$1,037,023**	**$5,923**	**$0**		**$2,243,692**
Contingency at 40%	0	145,044	335,254	414,809	2,369	0	0	897,477
Budgeted Material	**$0**	**$507,655**	**$1,173,390**	**$1,451,832**	**$8,292**	**$0**	**$0**	**$3,141,169**
Total AY $ with Contingency Estimate	**$0**	**$1,243,956**	**$2,176,954**	**$2,606,830**	**$331,473**	**$0**	**$0**	**$6,359,213**
Overall contingency %								**40.0% TPC**
								40.0% TEC

MAPS : Fully Burdened Bottoms-Up Cost Estimate
LANL Labor Costs and Overheads

sPHENIX MAPS Tracking LANL Labor and Overheads

Summary Estimate

	2016	2017	2018	2019	2020	2021	2022	Grand Total
sPHENIX Labor								
Fixed FY16 Direct Labor w/fringe		**126,568**	**381,040**	**109,392**	**332,192**	**46,560**		**$995,752**
Estimated Composite Indirect on Labor@ (LANL rates)	0	158,210	476,300	136,740	415,240	58,200	0	1,244,690
Fixed FY16 Fully Loaded Labor	**0**	**284,778**	**857,340**	**246,132**	**747,432**	**104,760**	**0**	2,240,442
Escalation @ 3.0%	0	8,543	52,212	22,816	93,803	16,685	0	194,060
Subtotal AY $	**0**	**293,321**	**909,552**	**268,948**	**841,235**	**121,445**	**0**	2,434,502
Contingency at 40%	0	117,329	363,821	107,579	336,494	48,578	0	973,801
Budgeted Labor	**0**	**410,650**	**1,273,373**	**376,528**	**1,177,729**	**170,023**	**0**	**3,408,302**
Adjusted sPHENIX M&S - MAPS			**$140,000**	**$2,157,710**				**$2,297,710**
Estimated Composite Indirect (LANL rates)	0	0	35,000	539,428	0	0	0	574,428
Subtotal FY 16 $	**$0**	**$0**	**$175,000**	**$2,697,138**	**$0**	**$0**		**$2,872,138**
Escalation @ 2% per FY	0	0	7,070	165,086	0	0		172,156
Estimate with Escalation	**$0**	**$0**	**$182,070**	**$2,862,224**	**$0**	**$0**		**$3,044,294**
Contingency at 40%	0	0	72,828	1,144,890	0	0	0	1,217,718
Budgeted Material	**$0**	**$0**	**$254,898**	**$4,007,113**	**$0**	**$0**	**$0**	**$4,262,011**
Total AY $ with Contingency Estimate	**$0**	**$410,650**	**$1,528,271**	**$4,383,641**	**$1,177,729**	**$170,023**	**$0**	**$7,670,314**
Overall contingency %								**40.0% TPC**
								40.0% TEC

MAPS : Fully Burdened Bottoms-Up Cost Estimate
BNL Labor Costs and Overheads

sPHENIX MAPS Tracking BNL Labor and Overheads

Summary Estimate

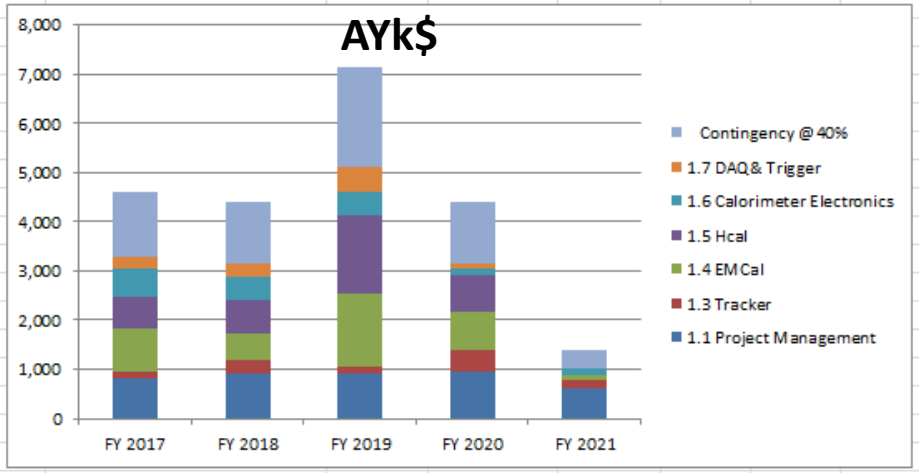
	2016	2017	2018	2019	2020	2021	2022	Grand Total
sPHENIX Labor								
Fixed FY16 Direct Labor w/fringe		**101,254**	**304,832**	**87,514**	**265,754**	**37,248**		**$796,602**
Estimated Composite Indirect on Labor@36.9%	0	37,363	112,483	32,293	98,063	13,745	0	293,946
Fixed FY16 Fully Loaded Labor	**0**	**138,617**	**417,315**	**119,806**	**363,817**	**50,993**	**0**	1,090,548
Escalation @ 3.0%	0	4,159	25,414	11,106	45,659	8,122	0	94,460
Subtotal AY $	**0**	**142,776**	**442,729**	**130,912**	**409,476**	**59,114**	**0**	1,185,007
Contingency at 40%	0	57,110	177,092	52,365	163,790	23,646	0	474,003
Budgeted Labor	**0**	**199,886**	**619,821**	**183,277**	**573,266**	**82,760**	**0**	**1,659,010**
Adjusted sPHENIX M&S - MAPS			**$140,000**	**$2,157,710**				**$2,297,710**
Estimated Composite Indirect (BNL rates)	0	0	13,202	203,472	0	0	0	216,674
Subtotal FY 16 $	**$0**	**$0**	**$153,202**	**$2,361,182**	**$0**	**$0**		**$2,514,384**
Escalation @ 2% per FY	0	0	6,189	144,523	0	0		150,713
Estimate with Escalation	**$0**	**$0**	**$159,391**	**$2,505,705**	**$0**	**$0**		**$2,665,097**
Contingency at 40%	0	0	63,757	1,002,282	0	0	0	1,066,039
Budgeted Material	**$0**	**$0**	**$223,148**	**$3,507,987**	**$0**	**$0**	**$0**	**$3,731,135**
Total AY $ with Contingency Estimate	**$0**	**$199,886**	**$842,969**	**$3,691,264**	**$573,266**	**$82,760**	**$0**	**$5,390,145**
Overall contingency %								**40.0% TPC**
								40.0% TEC

sPHENIX Budget Profile Components: Ops Support

Labor to support the Detector including Project Management, Tracker, EMCal, HCal, Calorimeter Electronics, DAQ/Trigger.

Operations Support = 21,900 AYk$

Category B: RHIC Operations Support



AY k$'s - with Extraordinary Construction Overhead Application

WBS	SYSTEM	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	Total
1.1	Project Management	829	915	906	949	628	4,227
1.3	Tracker	138	284	146	452	155	1,177
1.4	EMCal	868	513	1,476	778	98	3,733
1.5	Hcal	626	682	1,611	726	0	3,646
1.6	Calorimeter Electronics	571	468	470	157	121	1,788
1.7	DAQ& Trigger	245	272	485	81	0	1,083
	Baseline Total	3,277	3,134	5,095	3,145	1,002	15,653
	Contingency @40%	1,311	1,254	2,038	1,258	401	6,261
	Operations Total	**4588**	**4388**	**7133**	**4403**	**1403**	**21914**

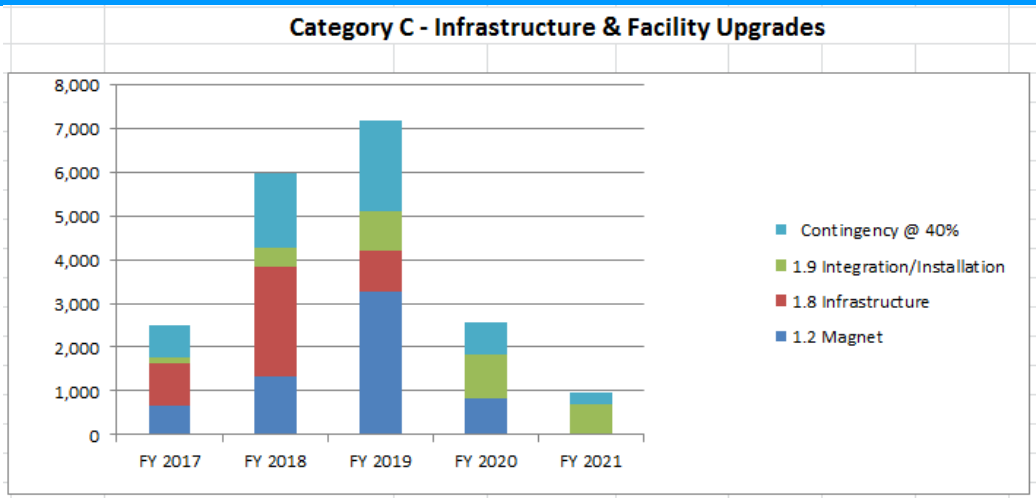
WBS	SYSTEM	Operations	Contingency	Total
1.1	Project Management	4,227	1,691	5,918
1.3	Tracker	1,177	471	1,647
1.4	EMCal	3,733	1,493	5,226
1.5	Hcal	3,646	1,458	5,104
1.6	Calorimeter Electronics	1,788	715	2,503
1.7	DAQ& Trigger	1,083	433	1,516
	Operations Totals	**15,653**	**6,261**	**21,914**

Budget Profile of C) Infrastructure and Facility Upgrade

Labor and M&S for the Infrastructure and Facility Upgrade of SC-Magnet Infrastructure, Detector Infrastructure and Installation/Integration

Infrastructure & Facility Upgrade = 19,200 AYk$

Sum Total of MIE+Ops Support + Facility and Infrastructure Upgrade:
29,500+ 21,900+19,200 = 70,600 AYk$

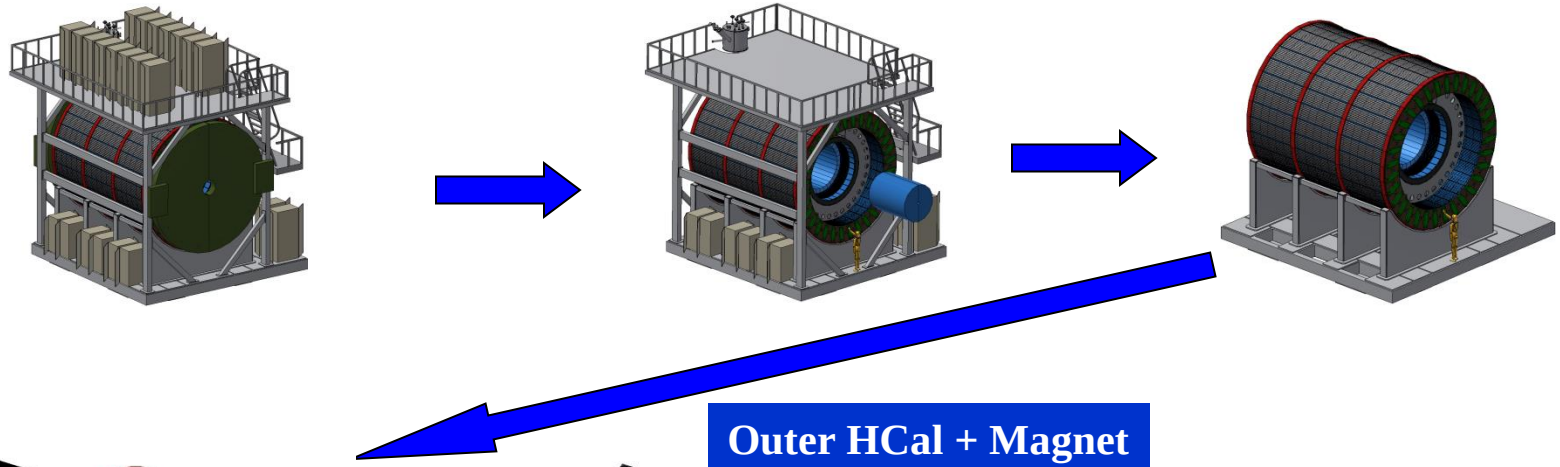


AY k$'s - with Extraordinary Construction Overhead Application

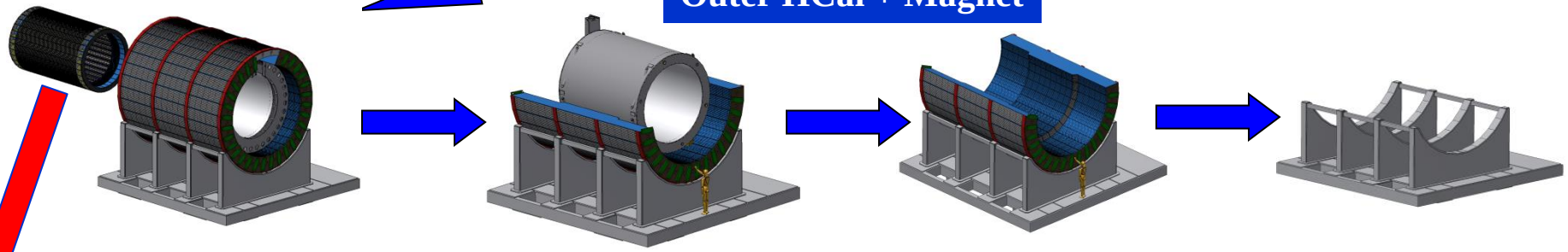
wbs	Infrastructure	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	Total
1.2	Magnet	678	1,321	3,263	827	0	6,089
1.8	Infrastructure	956	2,528	928	0	0	4,412
1.9	Integration/Installation	143	425	921	1,003	699	3,191
	Subtotal Infrastructure Upgades	1,778	4,274	5,111	1,830	699	13,692
	Contingency @ 40%	711	1,710	2,044	732	280	5,477
	Total	**1,778**	**5,984**	**7,155**	**2,562**	**979**	**19,169**

wbs	Infrastructure	Ops	Contingency	Total
1.2	Magnet	6,089	2,436	8,525
1.8	Infrastructure	4,412	1,765	6,177
1.9	Integration/Installation	3,191	1,276	4,467
	Total	**13,692**	**5,477**	**19,169**

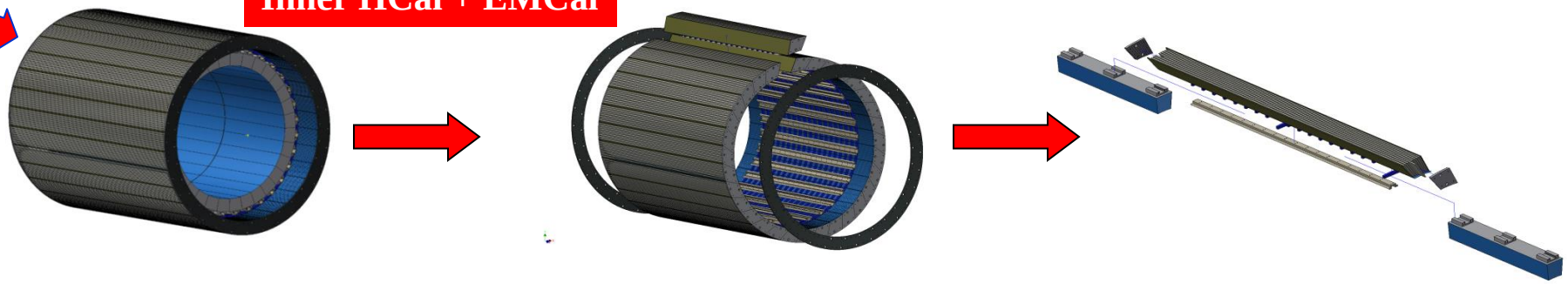
sPHENIX Deconstructed



Outer HCal + Magnet



Inner HCal + EMCal



Tim Hallman's slide from RHIC Users Meeting June 9